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Effects of Tillage Methods on Soil Organic Carbon and Total Nitrogen Content in the Loess Plateau

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Abstract In order to determine whether long-term no-tillage operation in the loess plateau threatens soil fertility and crop yield, a suitable high-yield and efficient tillage technology system was established. In the Changwu loess plateau agri-Gecological experiment station of the Northwest A&F University of Changwu County, Shaanxi Province, the no-tillage experimental field for three consecutive years was selected. In September 2015, no-tillage, tillage, and rotary tillage were carried out before winter wheat was sowed. After the harvest of winter wheat in 2016, soil organic carbon, total nitrogen and wheat yield in 0 – 30 cm soil layers under different tillage methods were analyzed. The results showed that the soil organic carbon and total nitrogen contents in the 0 – 30 cm soil layer decreased along the profile under the three tillage methods. In this study, the soil organic carbon and total nitrogen content in the 0 – 10 cm soil layer under different tillage methods were no-tillage > rotary tillage > tillage, the actual yield of winter yield in one hectare was tillage > rotary tillage > no-tillage, and there was significant difference in the actual yield of winter wheat only between the no-tillage and tillage.

Key words Loess plateau, Different tillage methods, Organic carbon, Total nitrogen, Wheat yield

1 Introduction

It is known that soil is the foundation for the survival of crops. Different tillage method of soil is an essential research content in agricultural production technology system. Choosing an appropriate tillage method exerts a positive effect on soil nutrient fixation, crop growth and yield formation . Compared with the traditional tillage, in recent years, there gradually appear protective tillage technologies such as no-tillage and subsoiling. Extensive research results both at home and abroad have shown that such protective tillage methods such as no-tillage and less tillage can reduce the wind erosion and alleviate water erosion, improve the soil physical and chemical properties, and also increase the crop yield . Nevertheless, with the extension of the implementation time of protective tillage, the disadvantages of protective tillage measures are also gradually emerging. For example, long-term less and no-tillage will lead to the accumulation of nutrients in the surface soil, which is not favorable for the uniform distribution of nutrients in the deep soil, accordingly influencing the crop yield.

As an important grain producing area in northwest China, the dry loess plateau area is located in arid and semi-arid areas and belongs to the rain-fed agriculture area. With the rise of protective tillage research, no-tillage operation has been carried out on the experimental field in the study area for three years. In order to find out the effects of long-term no-tillage operation on soil organic carbon, total nitrogen content, and crop yield in the study area, we performed different tillage treatments for the soil after long-term no-tillage. In this study, we selected the dry loess plateau area as the study area. In line with existing problems in the long-term no-tillage, we analyzed the effects of long-term no-tillage on the soil nutrients and yield of winter wheat at 0 – 30 cm soil layer, to provide a scientific reference for establishing a proper crop rotation system.

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2 Overview of the study area and research methods

2.1 Overview of the study area The experiment area is located in Changwu loess plateau agri-ecological experiment station of the Northwest A&F University of Changwu County of Shaanxi Province (35°14′ N, 107°40′ E). It belongs to arid agricultural area, and has temperate semi-humid monsoon climate. The crop planting is mainly one-crop-a-year wheat and maize. The experiment site is 1 200 m above sea level, with an annual average temperature of 9.1 ℃, sunshine hours of 2 226 h, and annual average rainfall of 578.5 mm. The soil in the experimental field is loessial soil, the field water holding capacity is 21% – 24%, the wilting humidity is 9% – 12%, the tillage soil. is 8.4, and the bulk density is 1.36 g/cm^3.

2.2 Experimental design and tillage method In September 2015, we carried out no-tillage, tillage, and rotary tillage treatments for the winter wheat before sowing in the no-tillage experimental field for three consecutive years, repeated three times, as listed in Table 1. The fertilization amount of each treatment was in accordance with the management mode of local farmers. The winter wheat variety adopted Changhan 58, and the seeding amount was 150 kg/ha, sowed on September 29, 2015, and harvested on June 4, 2016.

Table 1 Experimental treatment methods

Treatment	Tillage method
No-tillage	After the wheat is harvested, remove the straw and use no-tillage sowing machine to complete the sowing, fertilizing and repressing operations.
Tillage	After the wheat is harvested, remove the straw, apply fertilizer, conduct mechanical tillage (15 – 20 cm depth), and sow wheat.
Rotary-tillage	After the wheat is harvested, remove the straw, apply fertilizer, conduct rotary tillage (10 cm depth), and sow wheat.

2.3 Sampling scheme and determination methods After harvesting the wheat, we took three points on the experimental field with soil drill, took the soil depth to 30 cm, and collected sample according to 0 – 10, 10 – 20 and 20 – 30 cm, took about 40 – 50 g into the aluminum box, and measured the soil water content; separately, took some soil sample (350 – 450 g) and place in a resealable bag to measure the soil organic carbon and total nitrogen in the soil. According to the *Soil Agrochemical Analysis* (third edition) edited by Bao Shidan, we used the potassium dichromate oxidation method to determine the organic carbon content of soil samples and Semi-micro Kjeldahl method to determine the soil total nitrogen content.

2.4 Data processing We used the mean and standard deviation to indicate the soil organic carbon and total nitrogen content in different tillage methods and different depths, used ANOVA to analyze the effects of different tillage methods on soil organic carbon and total nitrogen content and yield of winter yield. Finally, we used *LSD* method to analyze the significance of the differences between the data ($P<0.05$), used Excel 2007 to conduct data processing and Spss 20 was used for data analysis.

3 Results and analysis

3.1 Soil organic carbon content under different tillage methods As shown in Table 2, the soil organic matter content at 0 – 30 cm soil layer under three tillage methods showed a decline trend along the soil profile, and there was significant difference in soil organic carbon content between no-tillage and rotary tillage at 0 – 10, 10 – 20 and 20 – 30 cm soil layers ($P<0.05$); there was no significant difference in the soil organic matter content between 0 – 10 and 10 – 20 cm soil layers of rotary tillage, but there was significant difference in soil organic carbon content with the 20 – 30 cm soil layer ($P<0.05$). The soil organic carbon content at the 0 – 10 cm soil layer under different tillage methods showed that no-tillage > rotary tillage > tillage, and no-tillage was significantly higher than tillage ($P<0.05$). At the 10 – 20 cm soil layer, the soil organic carbon content was manifested as no-tillage > tillage > rotary tillage, and there was no significant difference; at the 20 – 30 cm soil layer, the soil organic carbon content was manifested as tillage > rotary tillage > no-tillage, and there was significant difference ($P<0.05$).

3.2 Soil total nitrogen content under different tillage methods As shown in Table 3, the soil total nitrogen content at 0 – 30 cm soil layer under three tillage methods showed a decline trend along the soil profile, and there was significant difference in soil total nitrogen content between no-tillage and rotary tillage at 0 – 10 and 20 – 30 cm soil layers ($P<0.05$). The soil total nitrogen content at the 0 – 10 cm soil layer under different tillage methods showed that no-tillage > rotary tillage > tillage; at the 10 – 20 cm soil layer, the soil total nitrogen content was manifested as rotary-tillage > tillage > no-tillage; at the 20 – 30 cm soil layer, the soil total nitrogen content was manifested as tillage > rotary tillage > no-tillage, and there was no significant difference ($P<0.05$).

Table 2 Average soil organic carbon content under different tillage methods (± standard deviation) g/kg

Soil layer//cm	No-tillage	Tillage	Rotary-tillage
0 – 10	9.02 ± 0.279 aA	8.40 ± 0.203 bA	8.72 ± 0.088 abA
10 – 20	8.28 ± 0.164 aB	8.25 ± 0.266 aA	7.89 ± 0.227 aB
20 – 30	6.45 ± 0.064 cC	7.78 ± 0.221 aB	6.99 ± 0.376 bC

Note: small letters represent the difference in soil organic carbon content between different tillage methods at 0.05 level; capital letters represent the difference in soil organic carbon content between different soil layers at 0.05 level.

Table 3 Average soil total nitrogen content under different tillage methods (± standard deviation) g/kg

Soil layer//cm	No-tillage	Tillage	Rotary-tillage
0 – 10	0.96 ± 0.110 aA	0.86 ± 0.137 aA	0.94 ± 0.122 aA
10 – 20	0.74 ± 0.091 aAB	0.78 ± 0.090 aA	0.83 ± 0.074 aAB
20 – 30	0.66 ± 0.068 aB	0.75 ± 0.070 aA	0.71 ± 0.091 aB

Note: small letters represent the difference in soil total nitrogen content between different tillage methods at 0.05 level; capital letters represent the difference in soil total nitrogen content between different soil layers at 0.05 level.

3.3 Yield of winter wheat under different tillage methods From Table 4, it can be seen that there are no significant differences in the kernel number per spike, 100-grain weight and the theoretical yield under the three tillage methods. The number of effective spikes in one hectare of wheat was manifested as rotary tillage > tillage > no-tillage, and there were significant differences in the number of effective spikes between no-tillage, tillage, and rotary tillage.

Table 4 Yield of winter wheat under different tillage methods (± standard deviation)

Treatment	Number of effective spikes spikes /ha	Kernel number per spike	100-kernel weight//g	Theoretical yield kg/ha	Actual yield kg/ ha
No-tillage	4 186 667 ± 257 747 b	26 ± 2 b	5.091 3 ± 0.64 a	5 455 ± 215.7 a	4 502 ± 137.3 b
Tillage	4 930 000 ± 108 167 a	25 ± 2 a	5.040 3 ± 0.38 a	6 290 ± 277.6 a	5 062 ± 180.1 a
Rotary tillage	5 246 667 ± 109 697 a	23 ± 3 a	5.016 3 ± 0.36 a	6 057 ± 823.2 a	4 729 ± 207.1 ab

Note: small letters denote significant difference in the winter wheat yield between different tillage methods at 0.05 level.

4 Conclusions

The soil organic carbon and total nitrogen contents declined with the increase of soil layer, and under no-tillage and rotary tillage, the organic carbon and total nitrogen contents at the 0 – 10 cm soil layer were significantly different from that at deeper soil layers, indicating that the nutrients declined with the increase of the soil layer. The soil organic carbon and total nitrogen content in the 0 – 10 cm soil layer under different tillage methods were no-tillage > rotary tillage > tillage. No-tillage made the nutrients accumulate at the top soil, the tillage increased the depth of tillage and made the nutrients at the deeper layers distribute uniformly.

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